

* HASHING

- ① provides insert, delete, ~~and~~ search operations in $O(1)$ time
- ② NO duplicates are allowed.
- ③ Hashing is not used
 - when we have to find closer values.
 - data is arranged in sorted fashion
 - prefix searching → "gee" in "geeksforgeeks"

Avl or
Red black
tree

Application of Hashing

- Hash table is the second most used data structure
- for implementing dictionaries
- database indexing
- cryptography
- caches
- symbol tables in compilers / interpreters
- Routers
- getting data from databases

Direct Address table

We use keys as indexes of an array. on insert operation $arr[key] = 1$ on delete operation $arr[key] = 0$ and on search we just check if ($arr[key] = 1$)
return true;
else
return false;

- * If we have a range of $[0 - n]$ we can make an array of $arr[n]$
- * If we have range from $[m - n]$ we can use. $arr[n - m + 1]$ & $arr[key - m + 1]$

Examples of Hash Functions

| | | | | | |
|---|---|----|----|-----|-----|
| 0 | 1 | 10 | 20 | 918 | 919 |
|---|---|----|----|-----|-----|

table []

- * since array has random access

```
deletelij {           de search(i) {           insert(i) {  
    table[i] = 0;           return table[i];           table[i]=1;  
}                           }                           }  
                                3  
                                y
```

Problems

- ① large range of keys

- ② floating point numbers (as keys are used as index & index can only be positive integer)

- ③ keys can be strings.

Hashing

Take large universe of keys and by using hash function convert them to small values.

- * every time hash function must produce same value for same key
- * should generate value between 0 to m-1.
 $m \rightarrow$ size of hash table
- * hash function should be fast
- * should uniformly distribute large keys into hash table slots.

Collision handling

It is possible that two large-value maps to the same keys. This situation is called as collision.

• If data is known to us in advance, we can use perfect hashing to guarantee zero collision.

- ① if we do not know keys in advance, To handle collision, we have two techniques

- Chaining
- open Addressing

- linear probing
- quadratic probing
- double hashing

- ② for strings → weighted sum.

- ① \rightarrow sum of ASCII values of all the characters of string. Problem is we have same index for abc, acbd, adcb ...

- ② \rightarrow str \rightarrow "abcd"

\rightarrow $str[0] \times x^0 + str[1] \times x^1 + str[2] \times x^2 + str[3] \times x^3$. \rightarrow it producing unique keys most of the times as number x is prime no.

Universal Hashing

- group of hash functions, you pick one hash function randomly.

Chaining

Hash function

hash (value) \rightarrow value % 7
 keys \rightarrow {50, 21, 58, 17, 15, 49, 56, 122, 23, 125}

Hash Table \rightarrow Array of
linked list headers.

| | |
|---|----|
| 0 | 21 |
| 1 | 50 |
| 2 | 58 |
| 3 | 17 |
| 4 | 25 |
| 5 | |
| 6 | |
| 7 | |

- Basic funda is to link the suspended value with two head.

50% 4 \rightarrow 1
 21% 4 \rightarrow 0
 58% 4 \rightarrow 2
 17% 4 \rightarrow 3
 15% 4 \rightarrow 1
 49% 4 \rightarrow 0
 56% 4 \rightarrow 0

Performance of chaining

m \rightarrow no of slots
 n \rightarrow no of keys to be inserted
 load factor $\alpha = \frac{n}{m}$.

If hash table is small / load factor is big \rightarrow more no of collisions

Average chain length $\rightarrow \alpha$

expected time for search $\rightarrow O(1 + \alpha)$
 or insert $O(1) \rightarrow$ hash function

1. If worse distribution
 computation
 more complex
 unbalance distributed

under case will
 worst case lost
 all the same length
 map to memory
 index comp (O(n))
 chain compare

Data structures to store chains

\rightarrow linked list \rightarrow search $O(\alpha)$ \rightarrow but it is cache delete $O(\alpha)$ \rightarrow smart $O(\alpha)$

dynamically sized \rightarrow search/insert/
 delete $O(\alpha)$

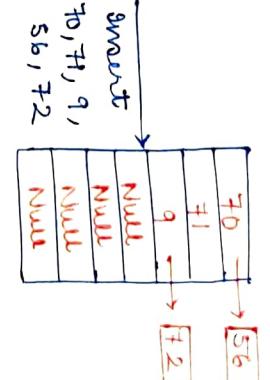
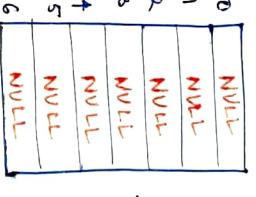
but it is provided
 cache friendliness

\rightarrow self Balancing \rightarrow search/insert/
 delete $O(\log \alpha)$

(AVL trees, red black tree.)

Implementation of linked list

Bucket $\rightarrow 7$



Basic structure of chains

struct mychain

int BUCKET;

list<int> *table;

mychain (int b) :

Bucket = b;

table = new list<int> [b];

void insert (int key) {

 table.push_back (key);

 cout << "inserted";

 cout << endl;

 cout << "size is";

 cout << table.size();

}

\rightarrow use to implement linked list

void insert (int key) {

 table.push_back (key);

 cout << "inserted";

 cout << endl;

 cout << "size is";

 cout << table.size();

}

we can use push-back to insert values in linked list

```
void insert (int key) {  
    int i = key % bucket;  
    table[i].push-back (key);  
}
```

```
void remove (int key)  
{  
    int i = key % bucket;  
    table[i].remove (key);  
}
```

3
bool search (int key) {
 int i = key % bucket;
 for (auto x : table[i])
 if (x == key)
 return true;
 return false;

Open Addressing

No of slots in the hash table \geq no of keys to be inserted

Advantage \rightarrow easier friendlier

Ex \rightarrow key $\rightarrow \{50, 51, 49, 16, 56, 15, 19\}$

| | |
|---|----|
| 0 | 44 |
| 1 | 50 |
| 2 | 51 |
| 3 | 16 |
| 4 | 56 |
| 5 | 15 |
| 6 | 19 |

hash(key) = key % 7

uniquely search for next empty slot when there is collision

- If the collision occurs at last index we search for new next slot in linear fashion

In delete operation

we cannot simply make a slot empty as during searching we even find empty slots and thus may modify our results

Ex

| |
|---|
| 2 |
| 3 |

delete \rightarrow

| |
|---|
| 2 |
| 4 |

Let $i = 1 \Rightarrow x = 4$
we start at
 $i = 1$ $arr[i] = 2$
move linearly
 $arr[i] = null$

wrong result \downarrow stop return false

hence we mark the slot as deleted slot (not true empty slot)

| | |
|---|----|
| 0 | 50 |
| 1 | 51 |
| 2 | 16 |
| 3 | 56 |
| 4 | 15 |
| 5 | 19 |

insert(50), insert(51), insert(15)
search(15), delete(15), search(15)

① In search operation, we first search in 1st index $i = key \% 7$
and if $arr[i]$ is not empty & contains some other value
we linearly move in search of x
we stop out search when

- (i) $arr[i] = x$ or return true.
- (ii) $arr[i] = null \rightarrow$ return false.
- (iii) or we traverse both at the same slot.

Problems with Linear probing

- Clusters are formed.
- Suppose we have a collision \rightarrow cluster of size 2
- If another key maps to the index of any one of them, cluster will grow \rightarrow 3
- Because of this if x is range $k+1$ [left]
all insert/search/delete operation become costly

We can write linear probing as

$$\text{hash}(\text{key}, i) = (\text{hash}(\text{key}) + i) \% m$$

$\hookrightarrow i$ is incremented

till 6 and if we don't

find any empty slot

it shows hash table is full.

Quadratic Probing

The problems of clusters are removed to much extent in this, instead of linearly searching for next slot, we search for i^2 , ($\text{next } 1^{\text{st}}$ slot), $i^2 (i+4)$, $i^2 (i+9)$...

* secondary clusters were formed.

$$\text{hash}(\text{key}, i) = (\text{h}(\text{key}) + i^2) \% m$$

there may be a case when quadratic probing will not find an empty slot even if there exist an empty slot

And it is proven that 'if $\alpha = 0.5 - \frac{2}{m}$

then only quadratic probing guarantees that it'll find free slot

Double Hashing

$$\text{hash}(\text{key}, i) = (\text{h}_1(\text{key}) + i \cdot \text{h}_2(\text{key})) \% m$$

\hookrightarrow two hash function

\rightarrow one hash function to find the slot
 \rightarrow second hash to find the slot if the calculate by the first is not free.

\rightarrow if m is relatively prime, then it always finds a free slot if there is one.

\rightarrow distributes keys more uniformly than quadratic probing

• NO clustering

and so can never return 0, because if it returns zeroes it will repeatedly perform collision.

$$\text{Ex- } 6 - \underline{\text{key}}^{\underline{1 \cdot 6}}, 6 - \{10-5\}$$

\downarrow give value $\log_2 (6-5)$

$$\text{key} \rightarrow \{49, 63, 56, 52, 54, 18\}$$

$$\text{hash}(\text{key}, i) = (\text{h}_1(\text{key}) + i \cdot \text{h}_2(\text{key})) \% m$$

| | |
|---|----|
| 0 | 49 |
| 1 | |
| 2 | 54 |
| 3 | 63 |
| 4 | |
| 5 | 56 |
| 6 | 18 |

$$\rightarrow \text{key} = 49$$

$$\text{hash}(49) = 0$$

$$\rightarrow \text{key} = 63$$

$$\text{hash}(63) = 0$$

$$\rightarrow \text{key} = 54$$

$$\text{hash}(54) = 0$$

$$\text{h}_1(\text{key}) = 54 \% 6$$

$$= 5$$

$$\text{h}_2(\text{key}) = 54 \% 4$$

$$= 2$$

$$\text{hash}(\text{key}) = (54 + 2 \cdot 5) \% 6$$

$$= 6$$

$$\text{hash}(\text{key}) = (54 + 2 \cdot 4) \% 6$$

$$= 6$$

$$\text{hash}(\text{key}) = (54 + 2 \cdot 3) \% 6$$

$$= 6$$

$$\text{hash}(\text{key}) = (54 + 2 \cdot 2) \% 6$$

$$= 6$$

$$\text{hash}(\text{key}) = (54 + 2 \cdot 1) \% 6$$

$$= 6$$

$$\text{hash}(\text{key}) = (54 + 2 \cdot 0) \% 6$$

$$= 6$$

$$\text{hash}(\text{key}) = (54 + 2 \cdot (-1)) \% 6$$

$$= 6$$

$$\text{hash}(\text{key}) = (54 + 2 \cdot (-2)) \% 6$$

$$= 6$$

$$\text{hash}(\text{key}) = (54 + 2 \cdot (-3)) \% 6$$

$$= 6$$

- we increment i each time we see collision

and initially we start with $i = 1$ for first collision.

Requirement

$\text{h}_1(\text{key}) \neq m$ should be relatively prime.

$$(5+12) \% 4 = 3 \rightarrow \text{filled}$$

$$17 \% 4 = 1 \rightarrow \text{empty}$$

$$\rightarrow \text{insert } 17 \rightarrow 3$$

$$(5+18) \% 4 = 23 \% 4 \rightarrow 2 \rightarrow \text{found}$$

Algorithm for open Addressing

```
void doubleHashing (key) {
    if (table is full)
        return error;
}
```

probe = $h_1(\text{key})$, offset = $h_2(\text{key})$,
while (table [probe] is occupied)

$$\text{probe.} = (\text{probe} + \text{offset}) \% \text{m};$$

table [probe] = key;

3. For linear probing offset $\rightarrow 1$.

Performance Analysis of search

$\alpha = n/m$ (should be ≤ 1) i.e. no of slots should be greater than keys

$$\text{let } \alpha = 0.8$$

it means 80% of table is occupied & 20% is still empty. (Y5)

To find an empty slot you need 5 iterations
ie. 4 filled slots + 1 empty slot.

$$\alpha = 0.9$$

Average no of probes. req $\rightarrow 9$

$$= \boxed{\frac{1}{1-\alpha}}$$

Implementation of Open Addressing

Assumption:-
-1, -2 are not present as keys.

+ is for ~~delete~~ empty
- is for deleted.

Structure in C++

```
struct myHash {
    int *arr;
    int cap, size;
}
```

myHash (int c) {
 cap = c;
 size = 0;
 arr = new int [cap];
}

```
for (int i=0; i< cap; i++) { empty array
    arr[i] = -1;
}
```

int hash (int key) {
 return key % cap; }

hash function

bool search (int key) { --- }

bool insert (int key) { --- }

bool erase (int key) { --- }

}

3. **bool search (int key) {**

int n = hash (key);

int i = n;

while (arr[i] != -1) {

if (arr[i] == key)

return ~~right~~ true;

i = (i+1) % cap;

if (i == n)

return false;

we return false when we find the key sample ;

we return true, when we find the key sample ;

bad input (int key):

```

if (size == cap)
    return false;
int i = max(key);
while (arr[i] != -1 && arr[i] != -2 && arr[i] != key) {
    i = (i + 1) % cap
}
if (arr[i] == key)
    return true;
else {
    arr[i] = key;
    size++;
    return true;
}

```

• we returned false.

① hash table is full.

② when key is already present

- + returned true.
- + Found spot for the key & size++.

- How to handle the cases when 1 & 2 are input key?
- As most libraries do, they store references or pointers. We don't use actual keys we use their pointers so far.
- ① empty - we can simply use NULL
- ② deleted - we have a dummy node, whenever we delete something we share pointer to reference to this dummy node.
- * this dummy node is not the part of class & is shared by all the members
- ### Comparison between two techniques
- | | |
|--------------------------|------------------------|
| Chaining (better) | Open Addressing |
|--------------------------|------------------------|
- ① Hash table would never fill.
- ② Table may become full and requires resizing after a point.
- There may be a case when key not new keys are added, for that we need to resize the table if it is full.
- ③ less sensitive to hash function
- ④ extra space is required for clustering.
- ⑤ cache friendliness is very poor.
- ⑥ no extra space required
- ⑦ Performance $\rightarrow O(1+\alpha)$
- Bottom Performance $1+0.9 \rightarrow 1.9$
- $\frac{1}{1-0.9} \approx \frac{1}{0.1} = 10$

Unordered set in C++

- It internally uses hashing for storing elements
- No particular order is maintained.
- Output can be any type permutation of elements

unordered_set<int> s;

s.insert(10) ← to insert an element

s.find(15) ← check if the element is present
 \downarrow
 if element is present →
 that element is returned
 \downarrow
 if element is not present
 iterator to element just after last
 element is returned (s.end())

s.begin() → iterator to first element

s.size() → gives the size of unordered set

s.clear() → it clears the unordered set completely

s.count() → alternative of find function and
 returns either 1 or 0
 \downarrow
 when element is present
 \downarrow
 when element is not present

s.erase() → s.erase(15) → find & remove 15

- we can pass iterator also.

s.erase(s.begin());

- we can also use, erase, to remove
 list of elements

s.erase(s.begin(), s.end())

→ iterator
 iterator

Unordered Map in C++ STL

- Based on Hashing
- Unordered container with fast insert, delete & search operations
- It stores key, value pair

unordered_map<string, int> m;

data type 1 → data type 2

m["gg"] = 20

if key is present i.e. if key value pair having
 "gg" as key is present, it returns the reference
 of the value corresponding to the key and if
 key is not present, it simply inserts the value
 and returns the reference to the key.

m["gg"] = 20

↗
 inserting
 key & returning
 reference to the
 value.
 ↗
 (initialised default
 as 0)

m.insert({ "courses", 154});

standard function for inserting a key-value pair

for (auto x : m)

cout << x.first << " " << x.second << endl;

↘
 traversing
 key
 ↗
 accessing
 value.

value

value

③ m.find("ide") → if m.find("ide") = m.end() key is not present

key

we can also get the corresponding value

auto it = m.find("ide");

if (it) = m.end()) {

cout < it->second;

y

→ "it is a pointer"

④ m.begin() → iterator pointing to 1st element

⑤ m.end() → iterator pointing beyond last element.

⑥ m.size() → number of key-value pairs

⑦ m.erase("ide") → remove key value pair

Time comp → O(1).

Count Distinct Elements

IP → {10, 20, 30, 20, 10} IP → {10, 10, 10}
OP → 3 OP → 1

Time complexity → O(n)
Space comp → O(n)

IP → {10, 20, 30}
OP → 3.

Naive Approach

```
int countDistinct(int arr[], int n){  
    int res = 0;  
    for (int i=0; i<n; i++) {  
        bool flag = false;  
        for (int j=0; j< i; j++) {  
            if (arr[i] == arr[j]) {  
                flag = true;  
                break;  
            }  
        }  
    }  
}
```

Efficient Solution

we are use to unordered set in st. when we are know and want all the elements in it. As we know in unordered set duplicates are not allowed. Hence we can simply check the size of set for distinct elements.

```
int countDistinct(int arr[], int n){  
    unordered_set<int> s;  
    for (int i=0; i<n; i++)  
        s.insert(arr[i]);  
    return s.size();  
}
```

we can directly pass integer array as
unordered_set<int> (arr, arr+n);

return res;

at any point after // i, we check from // 0 to i if element // is present or not.

Time complexity = O(n²)
Space comp = O(1)

Frequencies of Array Element

IP → {10, 12, 10, 15, 10, 20, 12, 12}.
OP → 10 - 3
 12 - 3
 15 - 1
 20 - 1

Naive approach → for every element traverse to the

right of it and calculate frequency.
You must also check, if that element is appeared at left, if it appears at left, it must have previous, just skip.

Efficient solution

using an unordered map.

```
int countFreq (int arr[], int n) {
```

unordered_map<int> m;

```
for (int x: arr) {
```

```
    m[x]++;
}
```

```
for (auto e: m) {
```

```
cout << e.first << " " << e.second;
```

```
Time comp → Θ(n)
```

```
Aux space → O(n)
```

Intersection of Two Arrays

```
IP a[] → {10, 15, 20, 15, 30, 30, 5}
```

```
b[] → {30, 5, 30, 80},
```

```
OP → {30, 5}.
```

Naive solution

```
int intersection (int a[], int b[], int m, int n) {
```

```
int res = 0;
```

```
for (int i=0; i<m; i++) {
```

```
bool flag = false;
```

```
for (int j=0; j<i; j++) {
```

```
    if (a[i] == b[j]) { flag = true;
```

```
        break;
```

```
    }
```

```
}
```

```
if (flag == true) { continue; }
```

```
else { cout << a[i] << endl; }
```

```
res++;
```

```
}
```

Union of two arrays

```
IP → {15, 20, 5, 15}, {15, 15, 15, 20, 10}
```

```
OP → 4 [15, 20, 5, 10]
```

Naive solution

- * Make an auxiliary array $c[m+n]$
- * Copy contents of A and B into auxiliary array
- * And then count distinct elements in that array $c[m+n]$

```
Time comp → O(m+n) * (m+n).
```

via 'a' to use unordered_set'

```
IP → a[] = {10, 15, 20, 15, 30, 30, 5}
```

```
b[] = {30, 5, 30, 80},
```

```
int intersection (int a[], int b[], int m, int n) {
```

```
unordered_set<int> s;
```

```
for (int i=0; i<m; i++) {
```

```
s.insert (a[i]);
```

```
for (int j=0; j<n; j++) {
```

```
if (s.find (b[j]) != s.end ()) {
```

```
res++;
```

```
s.erase (b[j]);
```

```
return res;
```

To ensure that duplicates etc
are not allowed.

Efficient solution $O(m+n)$.

Time comp → $O(m \times (m+n))$.

Efficient solution

We can want all the elements in an unordered set and can simply return its size.

int findUnordered (int arr[], int b[], int n, int m) {

unordered_set <int> s;

for (int i = 0; i < n; i++) {

s.insert (arr[i]);

for (int i = 0; i < n; i++) {

s.insert (b[i]);

return s.size();

}

Pair with a given sum in unsorted array

I/P → {3, 8, 5} S → 8

sum → 17

O/P → Yes

Name Approach

for (i → 0) {

for (j = i + 1 → n) {

if (arr[i] + arr[j] == sum)

return true; }

return false; }

Efficient solution

At any point before inserting an element i into the set look for $(sum - arr[i])$ inside the set.

By using set

unordered_set <int> s;

for (int i = 0; i < n; i++) {

if (s.find (sum - arr[i]) != s.end ())

return true;

s.insert (arr[i]);

return false;

return false;

}

Time-complexity → O(n)

Aux - space → O(n)

Subarray with zero sum

contiguous elements

I/P → {1, 4, 1, 3, -3, -10, 5}

O/P → Yes

O/P → {1, 4, -3, 2, 1}

O/P → {Yes}

Name solution

We start with current element as first element and then run loop for remaining elements to check if sum gets 0.

bad subarray (int arr[], int n)

for (int i = 0; i < n; i++) {

int curr = arr[i]; int j = i + 1;

while (curr != 0 && j < n) {

curr = curr + arr[j];

j++; }

if (curr == 0)

return true;

return false;

Time comp - O(n²)

Effective solution O(n)

prefix sum → $\underbrace{a_0 + a_1 + \dots + a_{i-1}}_{\text{prefix sum}} + a_i + a_{i+1} + \dots + a_{n-2} + a_{n-1}$. sum = 0

we will calculate

prefix sum and if

there is a ~~sum~~ ^{subarray} having 0 sum then the

prefix sum of two elements

will be equal (to check this we use hashing)

we will return true in

two cases.

① when the prefix sum

is already present in

set

where we calculated

prefix sum comes to be

i.e first i elements

sum up to 0.

Subarray with given sum

- This is the extension of previous problem

- Instead of comparing prefix sum = 0 we compare prefix sum = sum

- And we search for (prefixsum - sum) in the unordered set

prefix sum =
 (A) \downarrow
 (B) \downarrow

```
bool subarray (int arr[]) {
    unordered_set<int> s;
    int pre-sum = 0;
    for (int i = 0; i < n; i++) {
        pre-sum += arr[i];
        if (s.find (pre-sum) != s.end())
            return true;
    }
    return false;
}
```

```
int maxLen (vector<int> arr, int sum) {
    int res = 0;
    for (int i = 0; i < n; i++) {
        int curr-sum = 0;
        for (int j = i; j < n; j++) {
            curr-sum += arr[j];
            if (curr-sum == sum)
                res = max (res, j - i + 1);
        }
    }
    return res;
}
```

Time comp → $O(n^2)$

Longest subarray with given sum

I/P : arr [] = {5, 8, -4, 4, 9, -2, 2}. sum = 0

O/P : 3. (8, -4, 4)

I/P : arr [] = {3, 1, 0, 1, 8, 2, 3, 6}. sum = 5.

O/P : 5

I/P : arr [] = {8, 3, 7} sum = 15
 O/P : 0 (No subarray is present).

Naive Solution O(n^2)

• will find the lengths of subarray. using $(j-i+1)$ int maxlen (int arr[], int n, int sum) {

int res = 0;

for (int i = 0; i < n; i++) {

int curr-sum = 0;

for (int j = i; j < n; j++) {

curr-sum += arr[j];

if (curr-sum == sum)

res = max (res, j - i + 1);

res = max (res, j - i + 1);

res = max (res, j - i + 1);

res = max (res, j - i + 1);

res = max (res, j - i + 1);

res = max (res, j - i + 1);

res = max (res, j - i + 1);

res = max (res, j - i + 1);

res = max (res, j - i + 1);

res = max (res, j - i + 1);

length =
 $j - i + 1$
 $j - i + 1 = 3$

int maxSub (int arr[], int n, int m);

num.

int longsubsum (int arr[], int n) {

int res = 0;

for (int i = 0; i < n; i++) {

int c0 = c1 = 0;

for (int j = i; j < n; j++) {

if (arr[j] == 0)

c0++;

else c1++;

if (c0 == c1)

res = max (res, j - i + 1);

$O(n^2)$
Quadratic
Approach

if (m.find (pre-sum) == m.end ())

m.insert ({pre-sum, i});

if (m.find (pre-sum - sum) != m.end ())

res = max (res, i - m[pre-sum - sum]);

}

return res;

3

longest subarray with equal 0's and 1's.

IP arr → {1, 0, 1, 1, 0, 0}

OP →

IP → arr → {1, 1, 1, 1}

OP → 0

IP → {0, 0, 1, 1, 1, 0}

OP → 4

Naive solution

We maintain two pointers and calculate the number of 0's and 1's in the range.

arr[] → {1, 0, 1, 1, 0, 0}

at certain point

i ↑
↓
arr[i] → {1, 0, 1, 1, 0, 0}

c0 → 2
c1 → 3

3
return res;

3

Effective solution

Trick is to replace every 0 with -1 and calculate prefix sum and then find longestsubarray with 0 sum.

arr → {1, 0, 1, 1, 1, 0, 0}

int findmaxsubarray (int arr[], int n) {

int pref-sum = 0; unordered_map<int, int> m;

for (int i = 0; i < n; i++) {

pref-sum += arr[i];

if (pref-sum == 0)

res = max (res, i + 1);

if (arr[i]) pref-sum++;

else pref-sum--;

if (pref-sum == 0)

res = max (res, i + 1);

if (m.find (pref-sum) != m.end ())

res = max (res, i - m[pref-sum]);

else m.insert ({pref-sum, i});

return res;

longest common span with same num in binary array

$a[0] \rightarrow \{0, 1, 0, 0, 0, 0\}$

$a[1] \rightarrow \{1, 0, 1, 0, 0, 1\}$

$O/P \rightarrow 4$

$a[0] \rightarrow \{0, 1, 0, 1, 1, 1\}$

$a[1] \rightarrow \{1, 1, 1, 1, 1, 1\}$

$O/P \rightarrow 5$

$a[0] \rightarrow \{0, 0, 0\}$

$a[1] \rightarrow \{1, 1, 1\}$

$O/P \rightarrow 0.$

Naive Approach

Run two pointers i and j on both arrays. And now check sum of both, if sum is equal then we get common subarray, to get maximum, we will store the result of each time and then return max of it.

\Rightarrow maxCommon (vector $a[0], a[1], \dots, a[n-1]$, int n)

```

int res=0
for (int i=0; i<n; i++) {
    int sum1=0, sum2=0;
    for (int j=i; j<n; j++) {
        sum1+=a[0][j];
        sum2+=a[1][j];
    }
    if (sum1==sum2)
        res = max(res, j-i+1)
}
return res;

```

Time Complexity: $O(n^2)$

starting and ending indices should be same in subarray &

sum of elements of subarray must be equal.

there will be 4 cases

- ① first array contains 2 second also 4 $\rightarrow O$ (same sequence)
- ② 1st array contains 0 & second contains 0 $\rightarrow O$ (zero)
- ③ 1st array contains 1 & 2nd contains 0 $\rightarrow 1$ (first)
- ④ 1st array contains 0 & 2nd contains 1 $\rightarrow 1$ (second)

$a[0] \rightarrow \{0, 1, 0, 0, 0\}$

$a[1] \rightarrow \{1, 0, 1, 0, 0, 1\}$

$O/P \rightarrow \{1, 0, 1, 0, 0, 1\}$.

longest consecutive subsequence

$I/P - a[0] \rightarrow \{1, 9, 3, 4, 2, 20\}$ $O/P \rightarrow 4$

$I/P - a[1] \rightarrow \{8, 20, 7, 30\}$ $O/P \rightarrow 2$

Method-1

Sort the array and repeat update $curr_res$ whenever you see a consecutive value.

$1, 9, 3, 4, 2, 20 \rightarrow \underbrace{1, 2, 3, 4, 9, 20}_4, \max \rightarrow 4$

Time Complexity: $O(n \log n)$

Method-2

- create a hash table of size n and insert all elements into the hash table. And then traverse the array, for every element check if it is the starting point of sequence — if yes \rightarrow look for elements after it & add to $curr_res$

Effective solution

- we subtract one array (index to index) from another and then calculate the subarray with zero sum

addit. to curr res

Solution

- insert all elements of array into the unordered_map <int, int> freq;
- for (int i=0; i<n; i++)
 - if (arr[i] - 1 'not present in th).

curr = 1.

while (th contains arr[i]+curr)

curr++;

res = max(res, curr);

return res.

Count distinct Elements in every window of size k

I/P → arr[] = {10, 20, 20, 10, 30, 40, 10}.

Effective approach → use map

- create a frequency map of first k elements
- and then get the size of it
- on moving k further
 - decrement the frequency of freq[arr[i]]
 - if freq become 0 remove element.

~~vector<int> countDistinct (int arr[], int n, int k)~~

Method-1
Sort the array and then check the count of every element if $n/k < \text{count}$ we print that element

Time complexity → $O(n \log n)$

3

vectors <int> countDistinct (int arr[], int n, int k)

for (int i=0; i<k; i++)

freq[arr[i]]++;

for (int i=k; i<n; i++)

freq[arr[i-k]]--;

if (freq[arr[i-k]] == 0)

freq.erase(arr[i-k]);

freq[arr[i-k]]++;

res.push_back(freq.size());

return res;

3.

More than ($\lfloor \frac{n}{k} \rfloor$) occurrences

I/P → arr[] = {30, 10, 20, 20, 10, 20, 30, 30}

R = 4 n = 8

$$\frac{n}{R} = \frac{8}{4} = 2$$

O/P = {20, 30}

Method-2

Build and frequency map and then return more element whose frequency $> \lfloor \frac{n}{k} \rfloor$.

Time complexity → $O(n)$

Effective solution.

- we will use the concept of moore's voting algorithm.
- fact is $\text{res_count} \leq k-1$

let's suppose every element occurs n/k times

$$k * \left(\frac{n}{k} + 1\right) \leq n$$

$k = n+k \leq n$ (contradiction)

* Algorithm

- create an empty map m
- for ($i=0$; $i < n$; $i++$)
 - (a) if (m contains $a[i]$)
 $m[a[i]]++$;
 - (b) if ($m.size()$ is less than $(k-1)$).
 $m.put(a[i], 1)$.
 - (c) else decrease all values in m by one
 and if value becomes 0 remove it.
- For all elements in m , print the elements
 that actually appear more than n/k times -

$O(nk)$

STRING

- sequence of characters
- small set

contiguous integer value 'a' to 'z' and 'A' to 'Z' in both ASCII and UTF-16

C/C++

char: ASCII
8 bit

Java

UTF-16
16 bit

Two supports what

```
char x = 'a'  
cout << (int)x; // 97
```

Print the frequencies of character in sorted order

```
string str = "geekforgeeks";  
int count[26] = {0};
```

```
for (int i=0; i < str.length(); i++)
```

O/P

```
charat [str[i] - 'a']++;  
for (int i=0; i < 26; i++) {
```

```
    if (count[i] > 0) {
```

```
        cout << (char)(i + 'a') << ":";
```

```
        cout << count[i];
```

```
} }
```

```
3.
```

String in C++ [class array]
char str[] = "geek"
func

[g e e k \0 \0 \0 \0]

" " we give definite size
str[6] = "geek"

strlen → gives length of string
[g e e k \0 \0 \0 \0 \0]